

# **PROPAGATION AND SCATTERING IN LAYERS WITH ROUGH INTERFACES: SHALLOW WATER ACOUSTICS**

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## **LONG-TERM GOAL**

This research is being pursued in order provide good approximations for the behavior of acoustic fields propagating in layers bounded by statistically rough interfaces and to understand the importance of multiple scattering between interfaces.

## **SCIENTIFIC OBJECTIVE**

The immediate scientific objective of this research is to develop improved methods for computing the mean and the second moments of acoustic fields in waveguides with rough boundaries. Of particular concern is the problem of surface scattered fields returning to interact with a scattering interface many times. A secondary objective is to determine how to incorporate non-perturbative scattering amplitudes which have been developed for half-space scattering into the description of scattering in a waveguide where plane-waves do not provide a natural description of propagation.

## **APPROACH**

In a waveguide with many interfaces, the net field incident on one particular interface is the result of adding the field arising directly from any sources and the field which is multiply reflected and scattered from the remainder of the waveguide. The scattered field is determined by this net incident field plus the result of this field after it has been multiply scattered. To describe this complicated situation I have developed a compact formulation of the scattering in a waveguide with arbitrary sound speed profile which uses impedance operators to describe the effects of rough interfaces. This formulation is analogous to multiple scattering formalisms used in solid state physics to describe electron localization, and I have been able to adapt the methods used there to multimodal propagation in waveguides.

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## WORK COMPLETED AND RESULTS

The formalism mentioned above has been developed in detail to give the a formula for the scattered field in which the scattered field is given by the mean propagator from the sources to the interfaces followed by a multiple scattering operator, followed again by the mean propagator from the interfaces to the receiver. In this formula it is actually the vertical derivative of the mean propagators that appears rather than the mean propagator itself. The form of the fluctuating Green function is explicitly reciprocal. The appearance of derivatives of the mean field at the surfaces is, I believe, a new result.

I have used this formalism to see what effects multiple scattering might have on reverberation time histories. Because the mean field is used to propagate to and from the surfaces there is some extra attenuation that would be missed in a more conventional treatment. More importantly, the effective scattering operator in the ladder approximation ( i.e. the scattering operator computed as an infinite sum of simple scattering) exhibits diffusive behavior. The importance of this for reverberation is that in addition to modal contributions that decay in time exponentially, there is a diffusive contribution that decays only as  $1/t$ . The exponential behavior has been described by Ellis, starting from a much more phenomenological approach. He does not mention diffusive contributions.

The electron localization work is concerned with a class of multiple scattering events which gives rise to even slower decay --in fact, to no decay. As I understand things now, this would imply a sort of fossil'sound in the reverberation context. However, that supposes that there is no intrinsic attenuation--that the mean field is attenuated only because of energy-conserving scattering. The effect of these multiple scattering events has been observed in enhanced backscattering. It would be interesting if there were also a noticeable temporal effect.

## IMPACT/APPLICATION

The most important impact of this work is the questions it raises:

- 1) Are the echoes predicted by this computation observable? Are there long echoes in other settings, particularly settings in which a signal impinges from the outside on a rough layer?
- 2) Will the presence of diffusive behavior alter the interpretation of acoustic measurements of sea-floor topography?
- 3) Does the diffusive pole affect forward scattering? How might it affect the coherence of and signal processing of forward scattered signals?

## **RELATED PROJECTS**

A number of authors have treated the problem of propagation in waveguides with rough boundaries, for example, Beran and Frankenthal. For the most part, these treatments rely on parabolic or in some other sense one-way treatments of the scattering. The method used here makes no use of parabolic approximations, which is why one can discuss reverberation.

## **REFERENCES**

Dale D. Ellis, J. Acoust. Soc. Am. **97**, 2804 (1995).

M. J. Beran and S. Frankenthal, J. Acoust. Soc. Am. **91** 3203 (1992).